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(71)(72) Applicant and Inventor: PUCHIANU, Silviu [RO/GB]; The Innovation Centre, Aberdeen Offshore Tech. Park, Exploration Drive, Bridge of Don, Aberdeen AB23 8GX (GB).

(74) Agents: BERESFORD, Keith, Denis, Lewis et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DJ (GB).

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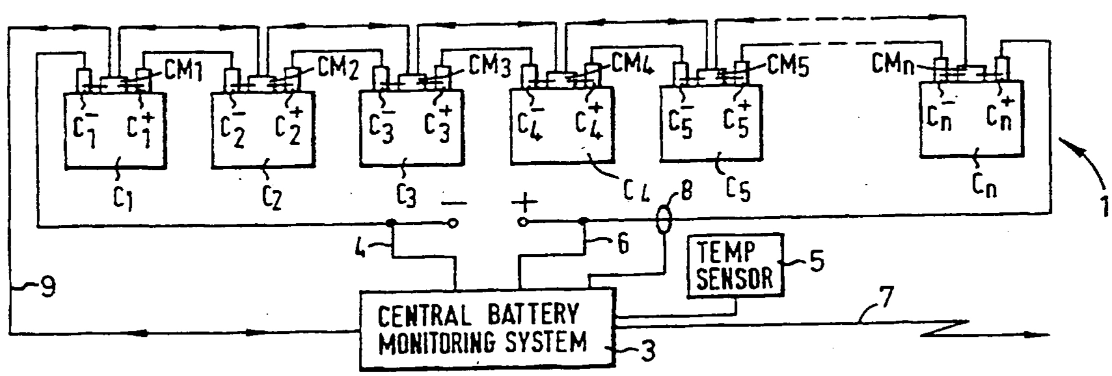


(57) Abstract

A battery signalling system is provided which can be used to monitor and/or control a battery (1) having a number of series connected battery cells (C_i). When used to monitor the battery cells, the battery signalling system can comprise a central battery monitoring system (3) for monitoring the industrial battery (1) as a whole, a number of cell monitoring devices (CM_i) for monitoring one or more battery cells (C_i) and a communication link (9) for connecting the cell monitoring devices (CM_i) in series in a daisy chain configuration to the central battery monitoring system (3). In operation, the central battery monitoring system (3) can poll each of the cell monitoring devices (CM_i) in turn and analyse the data received from a polled cell monitoring device (CM_i) to detect malfunctions and/or underperforming cells.

SIGNALLING SYSTEM

The present invention relates to a signalling system. The invention is applicable for use in a system for monitoring and/or controlling the cells of an industrial battery.

Industrial batteries comprise a number of rechargeable battery cells which can be electrically connected in various series and series-parallel combinations to provide a rechargeable battery having a desired output voltage. To recharge the battery, a current is passed through the cells in the opposite direction of current flow when the cells are working. There are many different types of battery cells available, but those most commonly used in industrial applications are lead acid battery cells, each of which provides 2 volts, and nickel-cadmium (Nicad) battery cells, each of which provides 1.2 volts.

The batteries are usually used as a back-up power supply for important systems in large industrial plants, such as off-shore oil rigs, power stations and the like. Since the batteries are provided as back-up in the event of a fault with the main generators, they must be constantly monitored and maintained so that they can provide power to the important systems for a preset minimum amount of time.

Many battery monitoring systems have been proposed which monitor the battery as a whole and provide an indication of the battery voltage. However, only a few systems have been proposed which can also monitor the individual cells which make up the battery. These systems use a number of monitoring devices, some of which are powered by the

transformers which have no DC path. The problem with this system is that to operate, each of the cell monitoring devices requires either an electrical to optical and an optical to electrical converter or a modulator and a demodulator, which makes them relatively expensive and inefficient since this additional circuitry requires more power from the cell.

There is therefore a need to provide a simple cell monitoring device which can monitor and report on the status of the cells of the battery, but which consumes minimal power from the cell which it is monitoring.

As mentioned above, existing battery monitoring systems monitor the battery and provide an indication of the battery voltage. However, battery voltage is not an indication of the capacity of the battery, i.e. the ability of the battery to provide energy. There is therefore also a need to provide a battery monitoring system which can give the user a fairly accurate estimate of how much load he can place on a battery and over what period of time.

The inventor has realised that it is possible to overcome the problem of having the cell monitoring devices operating at different voltages using simple electronic components and that therefore, there is no need for electrical isolation between the individual cell monitoring devices and the central monitoring system.

According to a first aspect, the present invention provides a signalling system for use with a plurality of series connected battery cells, comprising: a plurality of cell signalling devices, each to be powered by a respective one or more of the plurality of battery cells;

Each level shift circuit can comprise a simple electronic device, such as a comparator, which consumes a relatively small amount of power from the battery cell which powers the cell signalling device.

The first aspect of the present invention also provides a cell signalling device for use in the above defined signalling system, comprising: a power input terminal connectable to the cell or cells which is or are to power the cell signalling device; and at least one DC level shift circuit for receiving signals from an adjacent cell signalling device, for shifting the level of the received signal, and for outputting the level shifted signal for transmission to the communication link.

The first aspect of the present invention also provides a signalling kit comprising a plurality of the cell signalling devices defined above. The kit may also comprise the communication link for connecting the cell signalling devices in series.

The first aspect of the present invention also provides a signalling method using a plurality of series connected battery cells, comprising the steps of: providing a plurality of cell signalling devices and powering them with a respective one or more of the plurality of battery cells; providing a communication link which connects the plurality of cell signalling devices in series; receiving signals transmitted from an adjacent cell signalling device; shifting the level of the received signals; and outputting the level shifted signals to the communication link.

The present invention will now be described, by way of example only, with reference to the accompanying

Figure 7 schematically shows a battery comprising a number of battery cells connected in series, a central battery control system for controlling the battery as a whole and individual battery cell controllers for controlling the cells of the battery;

Figure 8 is a schematic diagram of one of the battery cell control devices shown in Figure 7;

Figure 9 is a schematic diagram of a battery cell monitoring and control device for use in a battery monitoring and control system embodying the present invention;

Figure 10 is a schematic representation of an industrial battery in which the cells of the battery are connected in a series-parallel configuration; and

Figure 11 is a schematic diagram of a system for monitoring a plurality of industrial batteries.

A first embodiment of the present invention will now be described with reference to Figures 1 to 5. Figure 1 schematically shows an industrial battery, generally indicated by reference numeral 1, comprising a number of lead acid battery cells C_1, C_2, C_3 ... C_n connected so that the negative terminal C_i^- of cell C_i is connected to the positive terminal C_{i-1}^+ of preceding cell C_{i-1} and the positive terminal C_i^+ of cell C_i is connected to the negative terminal C_{i+1}^- of the succeeding cell C_{i+1}, whereby the negative terminal C_1^- of the first cell C_1 is the negative terminal of the battery and the positive terminal C_n^+ of the last cell C_n is the positive terminal of the battery. Since the battery cells are lead acid, they each provide approximately 2 volts and the voltage of the battery as a whole will be approximately 2n volts. For industrial applications a voltage of 120 volts is

cell monitoring devices CM_i in series in a daisy chain configuration to the central battery monitoring system 3, so that communications from the central battery monitoring system 3 to the cell monitoring devices CM_i pass from left to right along the communication link 9 and communications from the cell monitoring devices CM_i to the central battery monitoring system 3 pass from right to left along the communication link 9. Each cell monitoring device CM_i has its own cell identification or address, which, in this embodiment, is set in advance using DIP-switches mounted in the device. This allows communications from the central battery monitoring system 3 to be directed to a specific cell monitoring device and allows the central battery monitoring system 3 to be able to identify the source of received communications.

The battery monitoring system shown in Figure 1 operates in two modes. In the first mode, the central battery monitoring system 3 monitors the condition of the industrial battery 1 as a whole and polls each of the cell monitoring devices CM_i in turn. During this mode, each of the cell monitoring devices CM_i listens to communications from the central battery monitoring system 3 on the communication link 9 and responds when it identifies a communication directed to it. When polled, each cell monitoring device CM_i performs a number of tests on the corresponding battery cell C_i and returns the results of the tests back to the central battery monitoring system 3 via the communication link 9.

In the second mode of operation, the central battery monitoring system 3 listens for communications on the communication link 9 from the cell monitoring devices CM_i indicating that there is a faulty condition with one of the battery cells C_i. In this second mode of operation,

monitoring system 3 can also measure the internal resistance of the individual cells from the data received from the individual cell monitoring devices CM_i received via the communication link 9 and the communication circuit 19.

In order to be able to measure the total battery capacity, i.e. the maximum amount of charge which can be stored in the battery, and the actual or remaining battery capacity at a given time point as a percentage of the total battery capacity, the central battery monitoring system 3 monitors how much charge is fed into the battery and how much charge is drawn from the battery. Unfortunately, since the charging and discharging characteristics of the battery are not one hundred percent efficient. Therefore, the estimated capacity derived by monitoring the charge alone is not very accurate. In fact, various factors affect the amount of charge which is input to or drawn from a battery during charging/discharging, including the ambient temperature, the magnitude of the charging/discharging current, the algorithm used for charging etc. Fortunately, many of these characteristics are known to the battery manufacturer and, in this embodiment the specific characteristics of the battery 1 are programmed into the central battery monitoring system 3. With this information, it is possible to determine more accurately how much charge has been stored in or withdrawn from the battery 1.

For example, if the battery 1 is charged with a charging current of 10 amps over a period of two hours at an ambient temperature of 20°C, and it is known that the efficiency characteristic of the battery is 95% for such a level of charging current and for that ambient

and/or supplied to the battery 1 since the last time the remaining battery capacity was determined and then by using the following equation:

$$RCP[t_1] = RCP[t_0] + \frac{100.CP[t_0,t_1]}{TCP} \qquad (2)$$

Where $CP[t_0,t_1]$ is calculated using equation 1 above. The initial estimate for the remaining battery capacity is set equal to the total working capacity of the battery after the battery has been fully charged.

To determine the internal resistance of the battery as a whole, the battery is connected to two different loads and the central battery monitoring system 3 monitors the current through the loads from which it determines the internal resistance of the whole battery.

As mentioned above, in addition to determining the total battery capacity, the remaining battery capacity and the battery internal resistance, the central battery monitoring system 3 also monitors data received from the cell monitoring devices CM_i via the communication circuit 19 and the communication link 9. If there is a fault with one of the battery cells C_i or if there is some other faulty condition, the CPU 11 can trigger a local alarm 23 to alert a technician that there is a fault with the battery 1 or with one or more of the battery cells C_i. In this embodiment, the conditions which define a fault and their thresholds are user definable and set in advance.

Although the central battery monitoring system 3 continuously monitors the battery 1, the sensor data and

recommended by the battery manufacturer for the battery 1.

Since the total battery capacity also decreases with time (due to ageing), the central battery monitoring system 3 is programmed to perform regular (for example daily or monthly) automated measurements of the total battery capacity and the battery internal resistance using the procedures outlined above. This allows the central battery monitoring system 3 to be able to build up a picture of the battery life characteristics and to be able to predict the battery end of life and the early detection of faulty conditions.

Figure 3 is a schematic diagram showing, in more detail, one of the cell monitoring devices CM_i. As shown, cell monitoring device CM_i comprises a microcontroller 31 for controlling the operation of the cell monitoring device CM_i and for analysing sensor data received from voltage interconnection sensor 33, cell voltage sensor 35, temperature sensor 37 and electrolyte level/PH sensor 39.

The voltage interconnection sensor 33 measures the voltage drop between the cell being monitored and its neighbouring cells, by measuring the potential difference between each terminal of the cell C_i and the respective terminal connections which connects cell C_i with its neighbouring cells. Ideally, there should be no voltage drop between each terminal and the corresponding terminal connection. However, due to chemical deposits accumulating at the cell terminals with time, or because of cell malfunction, a difference in potential between the cell terminals and the corresponding connectors sometimes exists, indicating that there is a fault, either with the battery cell C_i or with the

reference voltages between each of the cell monitoring devices CM_i, each cell monitoring device CM_i has an up-link 41 for transmitting data received from cell monitoring device CM_{i-1} to cell monitoring device CM_{i+1}, and a down-link 43 for transmitting data received from cell monitoring device CM_{i+1} to cell monitoring device CM_{i-1}.

The up-link 41 has a transceiver 45 for increasing the reference voltage of the data signal so that it can be received by the next cell monitoring device CM_{i+1}, while the down-link 43 has a transceiver 47 which reduces the reference voltage of the received data so that it can be received by the cell monitoring device CM_{i-1}. The up-link 41 and the down-link 43 are connected to the one wire communication link 9 via switches 49 and 51 which are controlled by microcontroller 31, as represented by arrows 52. The way in which the microcontroller 31 controls the position of the switches 49 and 51 for the above described two modes of operation will be apparent to those skilled in the art and will not be described here. The microcontroller 31 is connected to the up-link 41 by connection 53 so that it can listen for communications sent from the central battery monitoring system 3 which are directed to it. Similarly, the microcontroller 31 is connected to the down-link 43 by connection 55 so that the microcontroller 31 can send messages back to the central battery monitoring system 3, either upon being polled or upon detection of a fault.

In order to power the cell monitoring device CM_i, the positive terminal C_i^+ and the negative terminal C_i^- of cell C_i are connected to the input of a DC to DC convertor 57, which generates, relative to the ground or

side of Figure 5c shows the ground or reference voltage V_{REF}^{i-1} for cell C_{i-1} and shows that data pulses 65 output by cell monitoring device CM_{i-1} vary between V_{REF}^{i-1} + 5V and V_{REF}^{i-1} - 5V. In this embodiment, when the data is originally transmitted from the central battery monitoring system 3, the data pulses 65 will be transmitted from cell C_{i-1} to cell C_i and will be applied to the positive input of the comparator 61 on the up-link 41 of cell monitoring device CM_i via switch 49. As shown in Figure 5a, the received pulses are compared with V_{REF}^{i} - 2V (which is an approximation of the reference voltage V_{REF}^{i-1} of the cell C_{i-1} which generated the received pulses 65, since the cells are lead acid battery cells which provide approximately 2 volts each) and the data pulses 67 output by comparator 61 will correspond with the received data pulses 65 but will vary between V_{REF}^{i} + 5V and V_{REF}^{i} - 5V, as shown in the middle of Figure 5c. Therefore, the DC level of the square wave pulses has been increased by passing it through the comparator 61.

The output data pulses 67 are transmitted to the next cell monitoring device CM_{i+1} via switch 51 and communications link 9. The data pulses 67 output from comparator 61 are also input to the microcontroller 31 via connection 53, so that the microcontroller 31 can identify whether or not the communication from the central battery monitoring system 3 is directed to it. If the communication is directed to it, the microcontroller 31 processes the request, performs the necessary tests and transmits the appropriate data back to the central battery monitoring system 3.

When data pulses 69 are transmitted to cell monitoring device CM_i from cell monitoring device CM_{i+1} for

following advantages:

(1) There is no need for voltage isolation between the cell monitoring devices CM_i or between the first cell monitoring device CM_1 and the central battery monitoring system 3. Therefore, each cell monitoring device CM_i will only consume a few milli-amps and only requires very inexpensive and readily available DC to DC converters for converting the battery cell voltage to the supply voltage needed by the microcontroller 31 and the transceivers 45 and 47.

(2) Since electrical isolation is not required between the cell monitoring devices CM_i, there is no longer a need for relatively expensive voltage isolated links between the cell monitoring devices. In the embodiment described, each cell monitoring device CM_i is linked to its neighbours by a simple wire. The cost of the battery monitoring system is therefore low and system installation is simplified.

(3) Continuous monitoring of all the cells C_i in battery 1 becomes economical and practical, and the user can be informed in real-time if one or more of the battery cells C_i is under performing or is faulty.

(4) The internal resistance of each cell C_i can be determined in real-time and without having to disconnect the cell from the battery, since the central battery monitoring system 3 is capable of measuring battery charging and discharging current (which is the same as the cell current) and can correlate it with individual cell voltages (determined by the cell monitoring devices) in order to calculate each cell's internal resistance.

In particular, as shown in Figure 6, each cell monitoring device CM_i comprises a signal generator 71 which receives sensor signals from the cell voltage sensor 35 and the temperature sensor 37 and outputs, on line 73, a signal which varies in dependence upon the received sensor signals. The signal generator 71 may comprise a voltage controlled oscillator which outputs an alternating signal whose frequency varies in dependence upon an input voltage from, for example, the cell voltage sensor 35. The signal output from the signal generator 71 is applied to an output terminal 75 for transmission to the central battery monitoring system 3, via the communication link 9. In this embodiment, each cell monitoring device CM_i only transmits signals back to the central battery monitoring system 3, they can not receive messages from the central battery monitoring system. Therefore, only a down-link is required to receive signals at input terminal 77, transmitted from cell monitoring device CM_{i+1}.

As in the first embodiment, each cell monitoring device CM_i is powered by the cell C_i which it is monitoring. This is illustrated in Figure 6 by the connections C_i^+ and C_i^- which are connected to input terminals 74 and 76 respectively. Since the communication link 9 connects each of the cell monitoring devices CM_i in series in a daisy chain configuration, cell monitoring device CM_i will receive signals, at input terminal 77, from cell monitoring device CM_{i+1}. The received signals are applied to a DC level shift circuit 79 which reduces the DC level of the received signals and supplies them to the output terminal 75 for transmission to the next cell monitoring device CM_{i-1} in the communication link 9.

In the first two embodiments, the system described was

respectively, so as to control the amount of water and acid to be added to the battery cell C_i from the water tank 103 and the acid tank 105. The microcontroller 91 determines the amount of water and acid to add with reference to the sensor signals received from the electrolyte level/PH sensor 39.

In the first three embodiments, a central battery monitoring system or a central battery control system was provided which monitored or controlled the system as a whole. Figure 9 schematically shows a cell monitoring and control device CM&C_i which can be used in a combined battery control and monitoring system in which there is no central battery monitoring and control system and in which each cell monitoring and control device CM&C_i communicates directly with the other cell monitoring and control devices. As in the other embodiments, each cell monitoring and control device CM&C_i is powered by the cell which it is monitoring and controlling, as represented by inputs C_i^+ and C_i^- applied to input power terminals 115 and 117 respectively.

As shown in Figure 9, each cell monitoring and control device CM&C_i comprises a microcontroller 111 which receives sensor data from temperature sensor 37 and which outputs control data to output terminal 113 for controlling, for example, a liquid crystal display (not shown) mounted on the respective cell C_i.

In this embodiment, the communication link comprises two wires 9a and 9b and therefore, switches 49 and 51 are not required to connect the up-link and the down-link to the communication link 9. Wire 9a is used for passing communications up the series communication link 9 from cell monitoring and control device CM&C_i to cell

switches and current loops etc.

In the first embodiment the data transmitted between cells and between the first cell and the central battery monitoring systems varies between $V_{REF}^i \pm 5V$. The value of 5 volts was chosen for convenience since the normal operating voltage for the microcontroller 31 is 5 volts above the ground voltage for that cell. Theoretically, where the data transmitted between cells is given by $V_{REF}^i \pm X$ volts, X must be greater than half the cell voltage V_{CELL} in order for the comparator to be able to regenerate the received data pulses at the increased or decreased potential. Practically, since the battery cells and the comparators are not ideal, X should be at least two and a half times the cell voltage V_{CELL}.

In the first embodiment, a cell monitoring device was used to monitor each cell of the battery. In a cheaper implementation, each cell monitoring device CM_i could be used to monitor two or three series connected battery cells C_i. However, in such an embodiment, where the data transmitted between cell monitoring device is given by $V_{REF}^i \pm X$ volts, X should be at least two and a half times the difference in the reference potentials between adjacent cell monitoring devices.

In the first embodiment, the received data pulses are compared with an approximation of the ground or reference voltage of the cell which sent the data pulses. Alternatively, the received data pulses could simply be compared with the reference voltage of the cell monitoring device which receives the data pulses.

In the embodiments described, the cells are connected in series. It is possible to connect the battery cells C_i

can be transmitted in parallel.

In the above embodiments, a separate central battery monitoring system or a central battery control system was provided. In an alternative embodiment, a combined battery monitoring and control system could be used to both monitor and control the battery.

In the above described embodiments, a single battery comprising a plurality of battery cells, is monitored and/or controlled by a central battery monitoring and/or controlling system. Figure 11 shows an alternative embodiment where a plurality of batteries B_i are provided, and wherein each battery B_i is monitored by its own central battery monitoring system BM_i which communicates with a remote operator's terminal 151 via a data bus 153. The data bus 153 may be a proprietary data link or can be the public telephone exchange. In operation, each of the central battery monitoring systems BM_i monitors the respective battery B_i and reports its status back to the remote operator's terminal 151, where the condition of each of the batteries is monitored by a human operator. A similar system could also be provided for controlling or for monitoring and controlling a plurality of batteries.

The present invention is not limited by the exemplary embodiments described above, and various other modifications and embodiments will be apparent to those skilled in the art.

to increase the DC level of the received signals; and (iii) to output the level shifted signals for transmission to said communication link.

4. A signalling system according to any preceding claim, wherein each cell signalling device comprises at least one sensor input terminal operable to receive a signal from a sensor, which signal is indicative of a condition of the cell or cells which are to power the cell signalling device.

5. A signalling system according to claim 4, wherein each of said cell signalling devices comprises a sensor input terminal operable to receive a signal from an electrolyte level and/or electrolyte pH sensor, which signal is indicative of the electrolyte level and/or the electrolyte pH of the cell or cells which are to power the cell signalling device.

6. A signalling system according to claim 4 or 5, wherein each cell signalling device comprises a sensor input terminal operable to receive a signal from a voltage sensor, which signal is indicative of the voltage of the cell or cells which are to power the cell signalling device.

7. A signalling system according to any of claims 4 to 6, wherein each cell signalling device comprises a sensor input terminal which is operable to receive a signal from a temperature sensor, which signal is indicative of the temperature of the cell or cells which are to power the cell signalling device.

8. A signalling system according to any of claims 4 to 7, wherein each cell signalling device comprises a sensor

transfer paths of an adjacent cell signalling device.

12. A signalling system according to claim 9, wherein said communication link comprises a multi-wire communication bus, whereby plural data signals can be transmitted along said communication link at the same time.

13. A signalling system according any preceding claim, further comprising a central battery monitoring system for monitoring the battery as a whole, and wherein each of said cell signalling devices is operable to communicate, via said communication link, with said central battery monitoring system.

14. A signalling system according to claim 13, wherein each cell signalling device comprises:

at least one sensor input terminal operable to receive a signal from a sensor, which signal is indicative of a condition of the cell or cells which are to power the cell signalling device; and

a signal generator operable to generate a signal in dependence upon said sensor signal and to output said generated signal for transmission to said central battery monitoring system.

15. A signalling system according to claim 14, wherein said central battery monitoring system is operable to poll each of said plurality of cell signalling devices in turn, and wherein upon being polled, each cell signalling device is operable to return a signal back to said central battery monitoring system via said communication link, which is indicative of said condition of the cell which is to power said cell signalling device.

battery;

a second input terminal for receiving a signal indicative of the battery voltage;

means for discharging the battery from a fully charged condition in which no more charge can be stored in the battery to a fully discharged condition in which the battery voltage has been reduced to a predefined minimum operating voltage;

means for determining the period of time during which said battery is discharged; and

means for estimating the total working capacity of the battery in dependence upon said period of time and upon the current drawn from said battery during said period of time.

22. A signalling system according to claim 21, wherein said estimating means estimates said total working capacity of the battery in dependence upon the product of the level of said discharging current and said period of time.

23. A signalling system according to claim 21 or 22, wherein said central battery monitoring system further comprises an input terminal for receiving sensor signals indicative of at least one sensed operating condition of the battery, and wherein said estimating means estimates said total working capacity of the battery in dependence upon said sensor signals.

24. A signalling system according to claim 23, wherein said estimating means estimates said total working capacity of the battery in dependence upon a weighting factor indicative of the discharging efficiency of the battery for the at least one sensed operating condition.

working capacity of the battery.

30. A signalling system according to claim 28 or 29, wherein said means for estimating the remaining capacity of the battery operates periodically.

31. A signalling system according to claim 30, wherein said means for estimating the remaining capacity of the battery is operable (i) to monitor the level of current drawn from and/or supplied to the battery since the last estimate; and (ii) to estimate the change in capacity since the last estimate in dependence upon the current drawn from and/or supplied to the battery since the last estimate and the period of time since the last estimate.

32. A signalling system according to claim 31, wherein said central battery monitoring system comprises an input terminal for receiving sensor signals indicative of at least one sensed operating condition of the battery, and wherein said remaining capacity estimating means estimates said change in capacity in dependence upon said sensor signals.

33. A signalling system according to claim 32, wherein said remaining capacity estimating means estimates said change in capacity in dependence upon a weighting factor indicative of the charging and/or discharging efficiency of the battery for the at least sensed operating condition.

34. A signalling system according to claim 33, comprising means for storing predefined efficiency characteristics of the battery for different operating conditions and means for determining said weighting factor in dependence upon said sensor signals and the

39. A signalling system according to claim 38, wherein said central battery monitoring system further comprises means for predicting the battery end of life and/or future faults in dependence upon said record of previous estimates of the total working capacity of the battery.

40. A signalling system according to any of claims 21 to 39, wherein said central battery monitoring system comprises a power input terminal for receiving power from the battery which the central battery monitoring system is to monitor.

41. A signalling system according to any of claims 21 to 40, wherein said central battery monitoring system further comprises means for determining the internal resistance of the battery as a whole.

42. A signalling system according to any preceding claim, wherein each of said cell signalling devices is operable to receive a control signal from said communication link and comprises a signal generator operable to generate an actuation signal in dependence upon said received control signal and to output said generated actuation signal for controlling an actuator.

43. A signalling system according to claim 42, further comprising a central battery control system for transmitting said control signal to said communication link.

44. A signalling system according to claim 43, wherein said central battery control system is operable to transmit said control signal to each of said cell signalling devices in turn.

51. A signalling system according to claim 50, wherein said comparator comprises a voltage comparator.

52. A signalling system according to claim 51, wherein the communications transmitted over said communication link comprise square wave signals, and wherein each of said comparators is arranged to compare said square wave signals with a reference signal which is an approximation of the ground potential of the adjacent cell signalling device which transmitted the received square wave signals and to output a square wave signal in dependence upon whether or not the received square wave signal is greater or less than said reference signal.

53. A signalling system according to claim 52, wherein said comparator is operable to output a square wave voltage which varies between $X_{REF}^{i} \pm X$ volts, where X_{REF}^{i} is the ground or reference potential of the receiving cell signalling device and X is greater than half the cell voltage of the cell which is to power the cell signalling device.

54. A signalling system according to claim 53, wherein X is at least two and a half times the cell voltage of the cell which is to power the cell signalling device.

55. A signalling system according to claim 50, wherein said comparator comprises a current comparator.

56. A signalling system according to claim 50, wherein alternate voltage to current comparators and current to voltage comparators are used in adjacent cell signalling devices.

57. A signalling system according to any of claims 1 to

63. A signalling kit for use in a signalling system according to any of claims 1 to 60, comprising a plurality of cell signalling devices according to claim 61 or 62.

64. A signalling kit according to claim 63, further comprising a communication link for connecting said plurality of cell signalling devices in series.

65. A signalling system according to any of claims 1 to 60 in combination with a plurality of series connected battery cells, wherein one or more of said battery cells are connected to a respective one of said plurality of cell signalling devices, for powering said cell signalling devices.

66. A cell signalling device according to claim 61 or 62 in combination with a battery cell, wherein the terminals of said battery cell are connectable to said cell signalling device.

67. A signalling system for use with a plurality of systems each operating at a different reference voltage, comprising:

a plurality of signalling devices, each to be powered by a respective one or more of said plurality of systems; and

a communication link connecting said plurality of signalling devices in series, such that the position of each signalling device in said series communication link depends upon the reference voltage of the system or systems which are to power the signalling device;

wherein at least one of said signalling devices comprises a DC level shift circuit which is operable (i) to receive signals transmitted from an adjacent

applying a load to the battery to thereby draw a discharge current from the battery;

means for monitoring the battery voltage and the level of said discharge current during the discharging of the battery and for outputting a signal when the battery voltage has reached a predefined minimum operating voltage indicative of the battery discharge limit;

means for terminating the discharging of the battery by removing said load from the battery when said signal is output by said monitoring means;

means for determining the period of time between the initiation and the termination of said battery discharging; and

means for estimating the total working capacity of the battery in dependence upon the level of said discharging current and said period of time.

71. An apparatus for estimating the total working capacity of a battery, comprising:

a first input terminal for receiving a signal indicative of the current drawn from or supplied to the battery;

a second input terminal for receiving a signal indicative of the battery voltage;

means for causing the battery to discharge from a fully charged condition in which no more charge can be stored in the battery to a fully discharged condition in which the battery voltage has been reduced to a predefined minimum operating voltage;

means for determining the period of time during which said battery is discharged; and

means for estimating the total working capacity of the battery in dependence upon said period of time and upon the current drawn from the battery during said

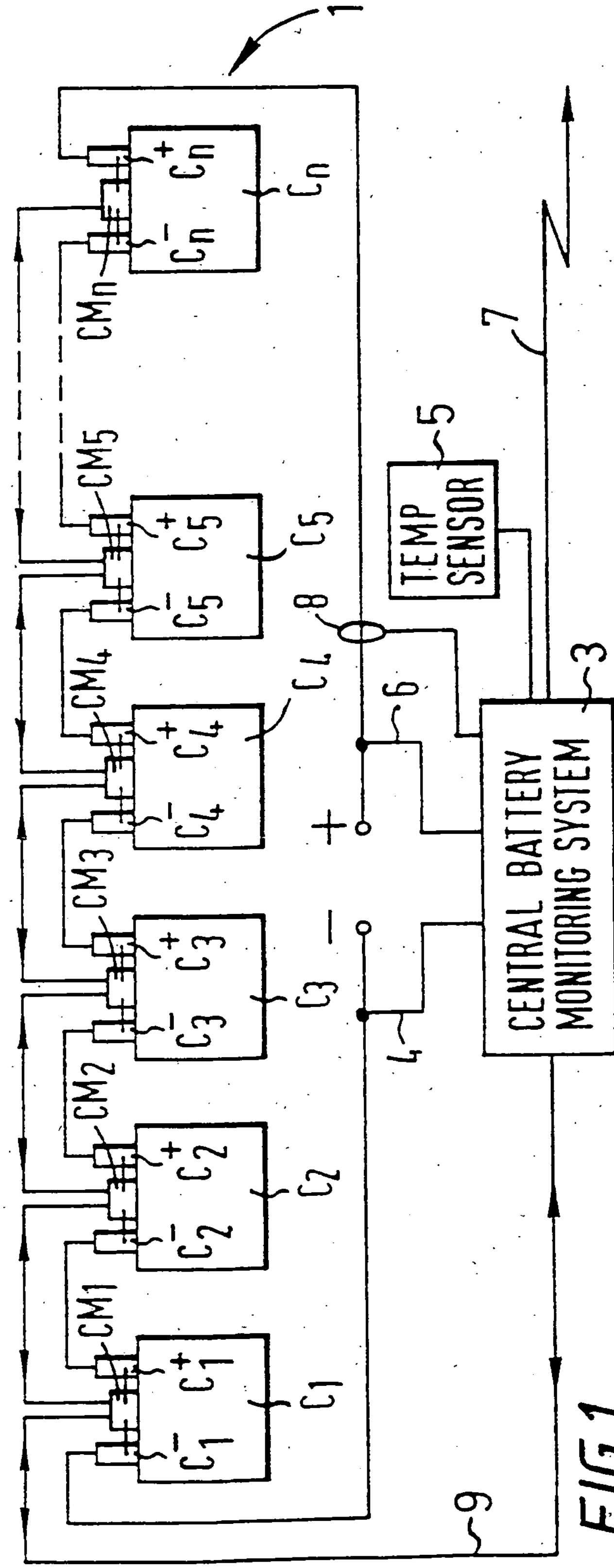

1
CENTRAL BATTERY MONITORING SYSTEM
TEMP SENSOR
CM1
CM2
CM3
CM4
CM5
CMn
C1
C2
C3
C4
C5
Cn
+
−
3
4
5
6
7
8
9

FIG.1

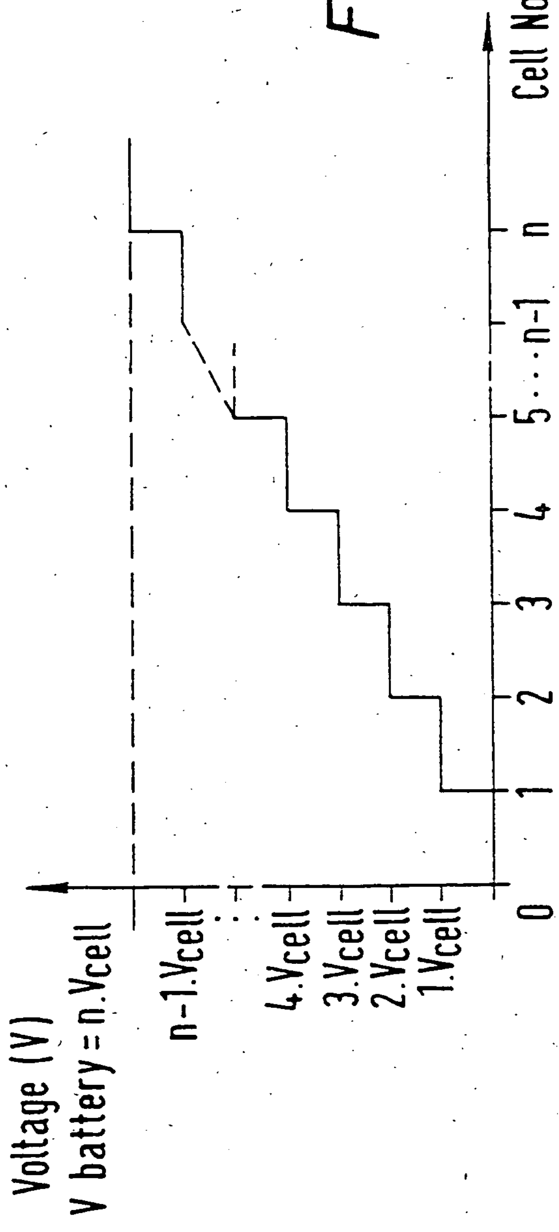

Voltage (V)
V battery = n.Vcell
n-1.Vcell
4.Vcell
3.Vcell
2.Vcell
1.Vcell
0
1
2
3
4
5 . . . n-1
n
Cell No.

FIG.4

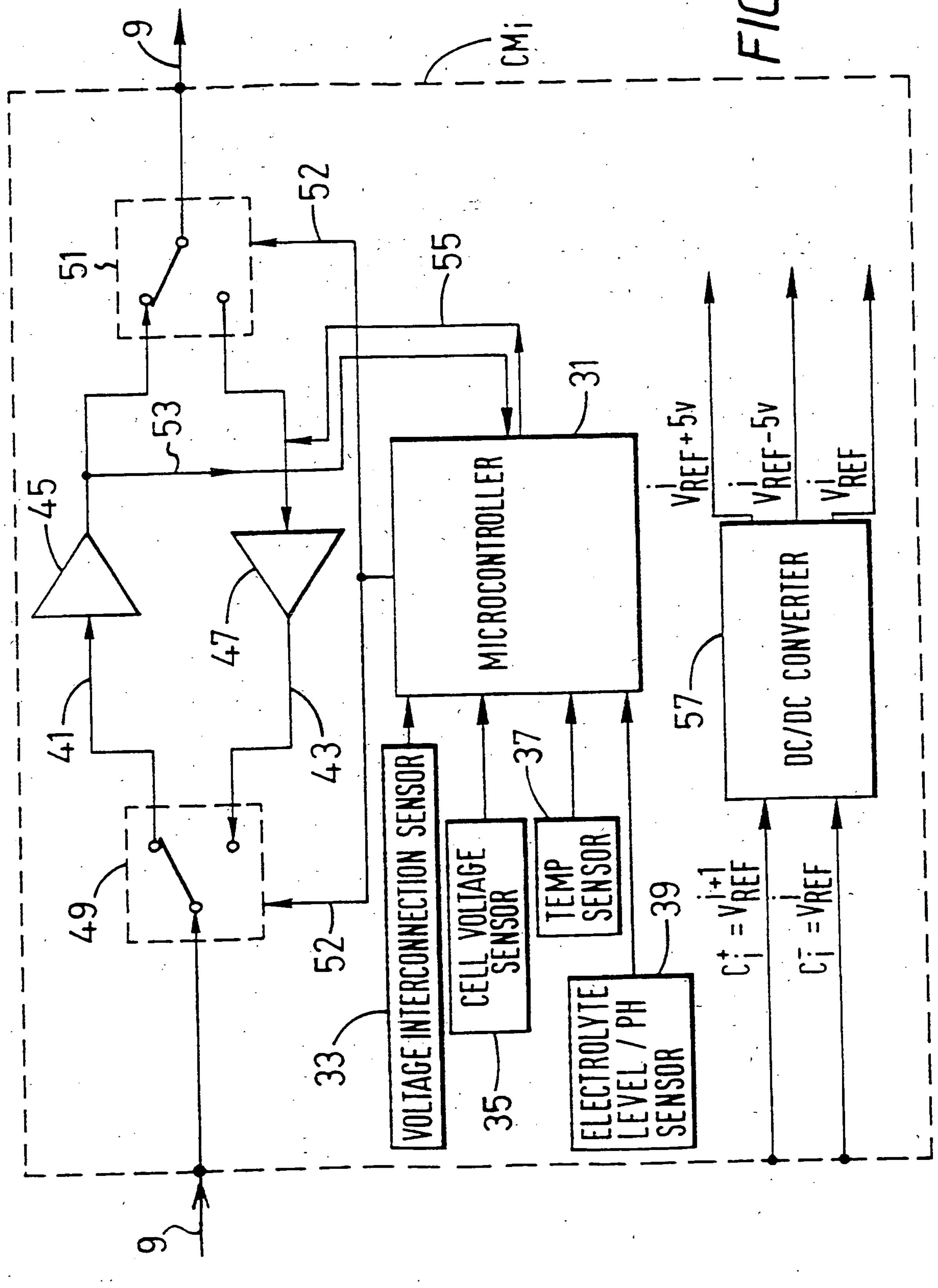
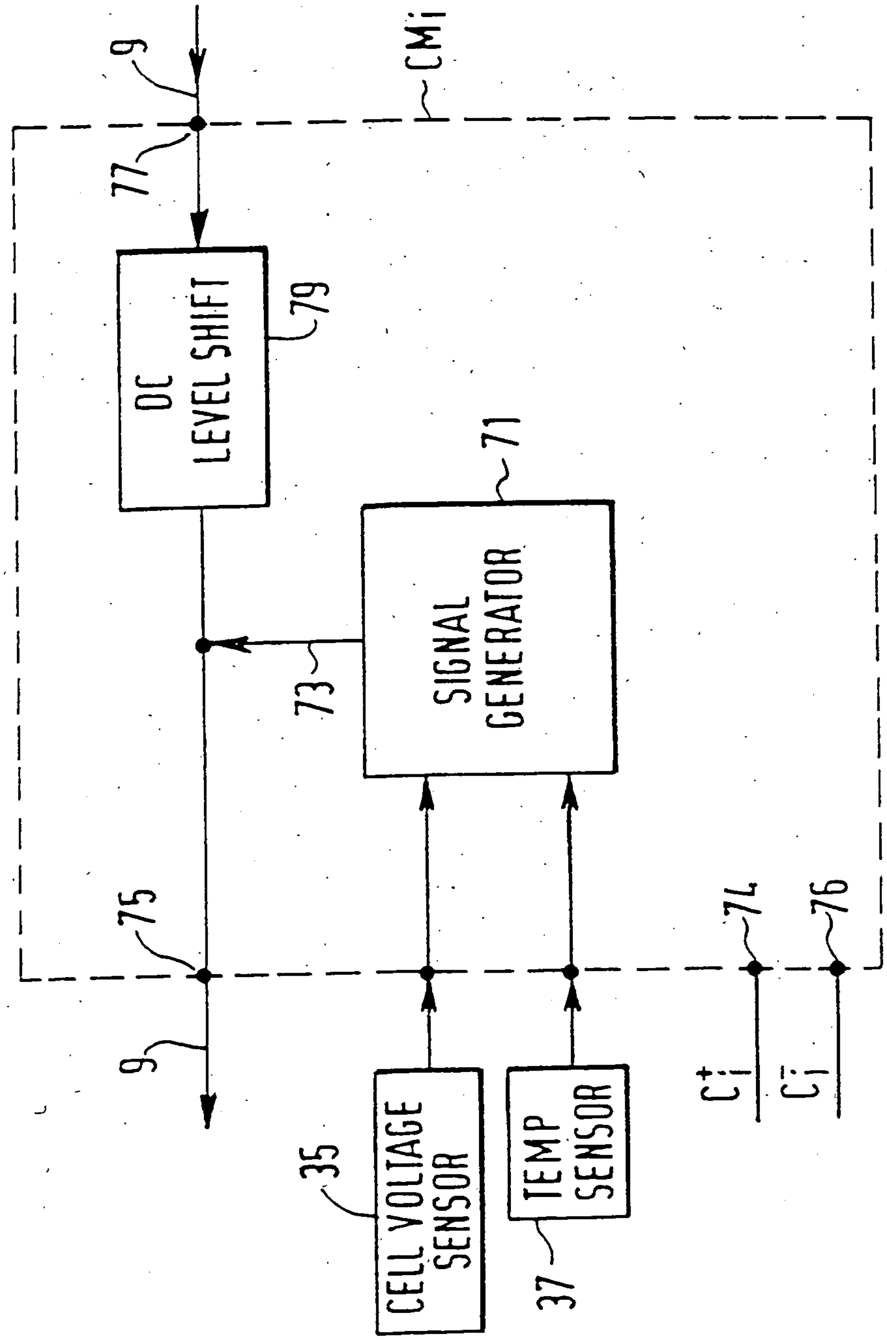

9
CMi
52
51
55
31
53
45
MICROCONTROLLER
$V^i_{REF}+5v$
$V^i_{REF}-5v$
V^i_{REF}
47
DC/DC CONVERTER
57
41
43
37
49
VOLTAGE INTERCONNECTION SENSOR
CELL VOLTAGE SENSOR
TEMP SENSOR
39
$C^+_i = V^{i+1}_{REF}$
$C^-_i = V^i_{REF}$
52
33
35
ELECTROLYTE LEVEL / PH SENSOR
9

FIG.3

FIG. 6


9
CMi
77
DC LEVEL SHIFT
79
71
SIGNAL GENERATOR
73
75
74
76
9
CELL VOLTAGE SENSOR
35
TEMP SENSOR
37
C_i^+
C_i^-

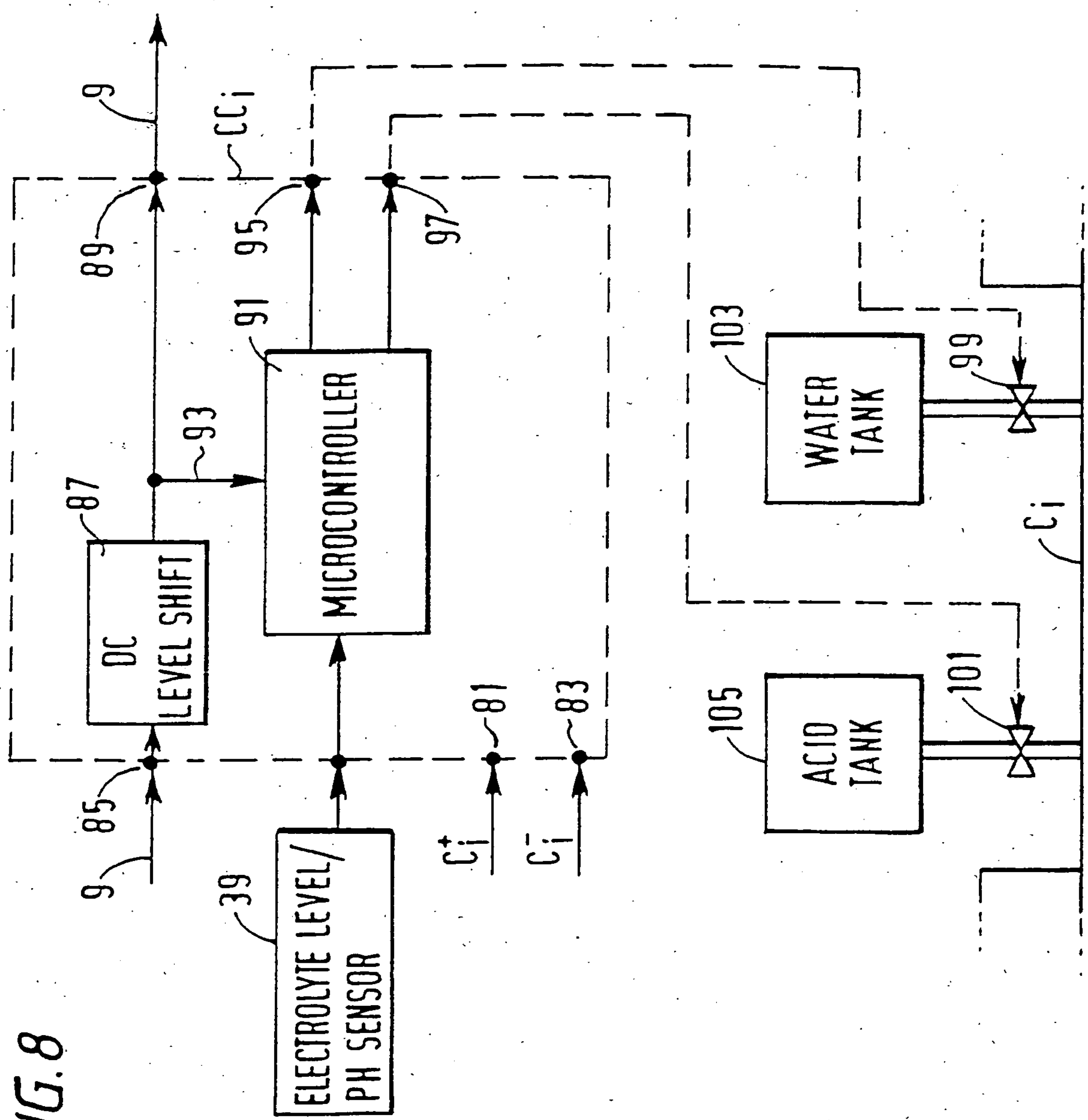
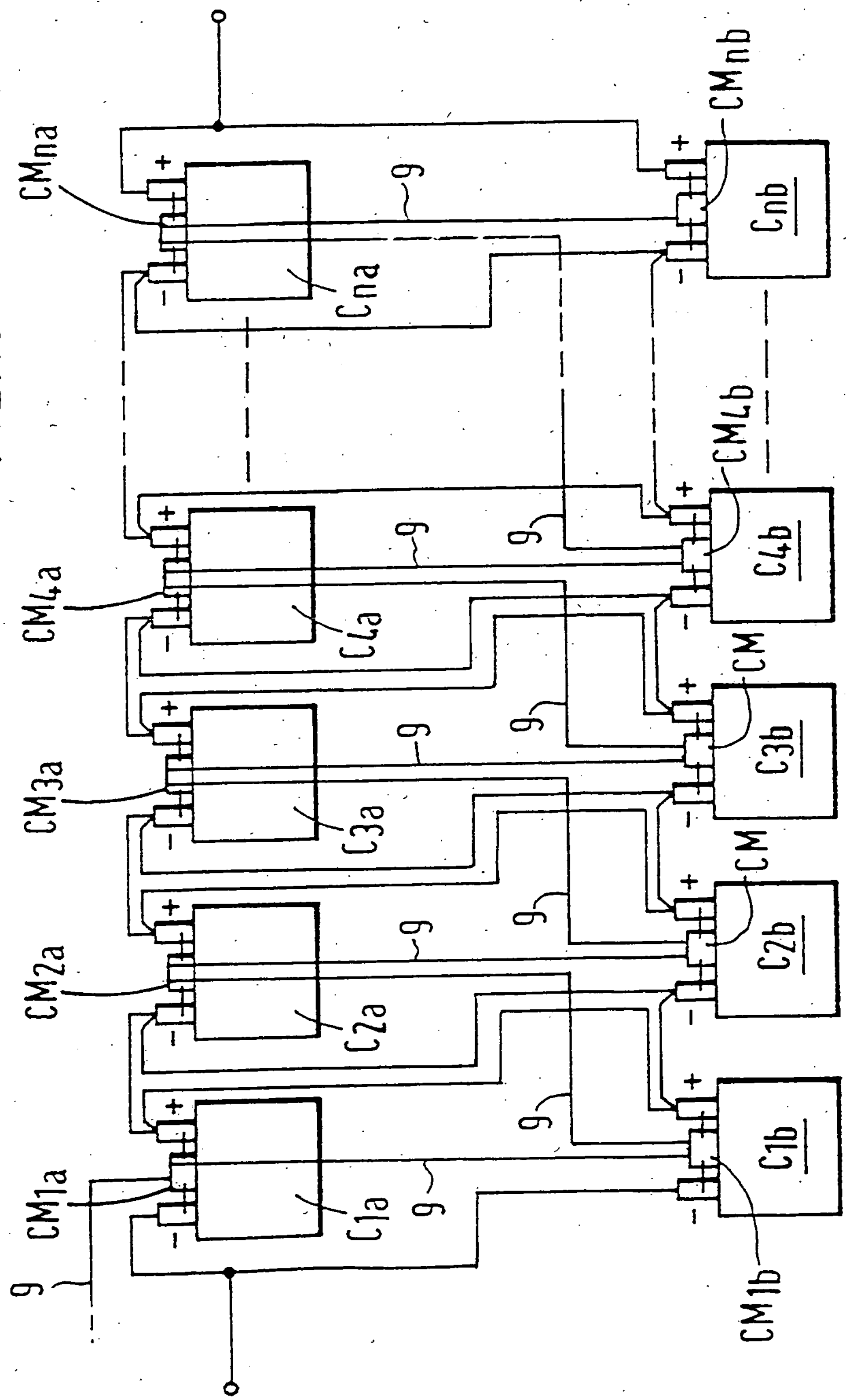

9
CC$_i$
89
95
97
91
93
87
DC
LEVEL SHIFT
MICROCONTROLLER
85
9
81
83
C_i^+
C_i^-
39
ELECTROLYTE LEVEL/
PH SENSOR
103
WATER
TANK
99
C_i
105
ACID
TANK
101

FIG. 8

FIG. 10


CMna
Cna
CMnb
Cnb
CM4a
C4a
CM4b
C4b
CM3a
C3a
CM
C3b
CM2a
C2a
CM
C2b
CM1a
C1a
C1b
CM1b
9

PCT

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(71)(72) Applicant and Inventor: PUCHIANU, Silviu [RO/GB]; The Innovation Centre, Aberdeen Offshore Tech. Park, Exploration Drive, Bridge of Don, Aberdeen AB23 8GX (GB).

(74) Agents: BERESFORD, Keith, Denis, Lewis et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DJ (GB).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

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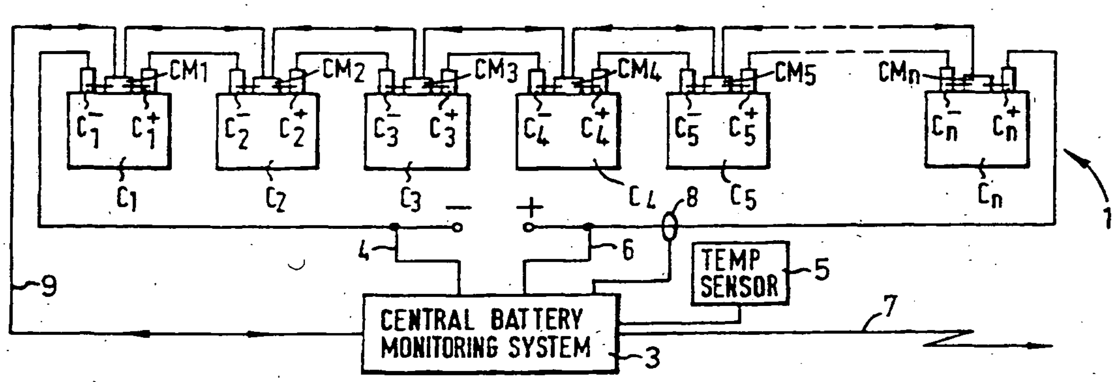

(57) Abstract

A battery signalling system is provided which can be used to monitor and/or control a battery (1) having a number of series connected battery cells (C_i). When used to monitor the battery cells, the battery signalling system can comprise a central battery monitoring system (3) for monitoring the industrial battery (1) as a whole, a number of cell monitoring devices (CM_i) for monitoring one or more battery cells (C_i) and a communication link (9) for connecting the cell monitoring devices (CM_i) in series in a daisy chain configuration to the central battery monitoring system (3). In operation, the central battery monitoring system (3) can poll each of the cell monitoring devices (CM_i) in turn and analyse the data received from a polled cell monitoring device (CM_i) to detect malfunctions and/or underperforming cells.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00170

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02J H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 93 08629 A (NORVIK TECHNOLOGIES INC) 29 April 1993 see page 2, paragraph 2 - page 4, paragraph 1; claim 1 ---	1,67,69
A	WO 83 00740 A (TOWMOTOR CORP) 3 March 1983 see claim 1 -----	1-3,67, 69

☐ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 June 1998	11.08.98

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Andrews, M

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 98/00170

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9308629	A	29-04-1993	US	5206578	A	27-04-1993
			AT	147204	T	15-01-1997
			CA	2121471	A	29-04-1993
			DE	69216432	D	13-02-1997
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WO 8300740	A	03-03-1983	CA	1179014	A	04-12-1984
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